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ABSTRACT

This study focused on high school students' conceptions and substantial concept change learning processes when studying the kinetic theory of gases. The study was conducted in 1998 in four classes of a public metropolitan high school in South Korea. Data was collected through semistructured and in-depth interviews and participant observation of three core participants. Each core participant was interviewed individually or in a group four times before, during (twice), and after instruction. Additional data sources included tests, questionnaires, written quizzes, and student profiles written by teachers. Three conceptual types were distinguished: (1) superficial terms speaking; (2) partial sense making; and (3) elaboration of conceptual networks. The characteristics of conceptual change learning processes were investigated. In superficial terms speaking and partial sense making types, students had defective frameworks, passive recognition, and motivational beliefs about scientific knowledge and about science learning. These things made them very passive learners. On the other hand, students of the causal sense making type generally has a scientific conceptual framework and active recognition of scientific knowledge and motivational beliefs. They had their own intrinsic authority and experienced effective conceptual change. The finding that only students making scientific sense about fundamental theoretical concepts experienced successful conceptual change indicates that the active participation of students themselves is needed in scientific sense making. This also implies that science teaching and curriculum organization should be constructed for students to make basic conceptions. To make chemistry learning effective, it is necessary to develop and use proper teaching sequences and strategies in the presupposition of understanding conceptual types of students and their teachers. (Contains 6 figures and 30 references.) (Author/SLD)

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Conceptual Types of Korean High School Students and Their Influences on Learning Style

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ABSTRACT

This study focuses on high school students' conceptions and substantial conceptual change learning processes on kinetic theory of gases. This study was implemented in the second semester of 1998 as a naturalistic study in four classes in a metropolitan high school. Data has been collected by semi-structured and in-depth interviews and participant observations. The three core participants of this study have been selected and examined. Each core participant was interviewed individually or in a group four times; in before instruction, mid, late and after of the semester. Instructional context was small group discussion under entirely cooperative condition and accomplished eight class hours during this period on four topics. Additional data sources included tests, questionnaires, written quizzes, and students' profiles written by teachers etc.

As a result of this study, three conceptual types were distinguished as superficial terms-speaking, partial sense-making, and causal sense-making by the degrees of organization and elaboration of conceptual networks. According to these types, the characteristics of conceptual change learning processes were investigated. In superficial terms-speaking and partial sense-making types, students had defective frameworks, passive recognition and motivational beliefs about scientific knowledge and about science learning. These made them very passive learners. On the other side, students of causal sense-making type generally had scientific conceptual framework, active recognition of scientific knowledge and of motivational beliefs. They had their own intrinsic authority and experienced effective conceptual change.

The fact that only students making scientific senses about fundamental theoretical concepts experienced successful conceptual change indicates that the active participation of students themselves is needed in the scientific sense making. It also implicates that science teaching and curriculum organization should be constructed for students to make basic conceptions as scientific conceptual knowledge. Therefore, in order to make the chemistry learning substantially effective, we need to develop and use proper teaching sequences and strategies in presupposition of understanding conceptual types of students themselves and of teachers.

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I. Introduction

Almost all works of science education literature published during the last two decades, which includes numerous studies about conceptual change and argumentation in relation to the so-called Alternative Framework Movement (Gilbert & Watt, 1983), tells us that learners' prior knowledge-alternative frameworks of reference (Driver & Easley, 1978)- is often recognized by learners themselves as most stable explanatory frameworks of the world. It often comes into conflict with the knowledge taught in school and resists to change into scientific conceptions they are expected to learn (Pfundt & Duit, 1991; White & Gunstone, 1989; Engel-Clough & Driver, 1986; Osborne & Freyberg, 1985; West & Pines, 1985; Driver & Erickson, 1983). Therefore the concern of science education researchers and educators has been focused on the way of incorporating learners' conceptual knowledge into scientific knowledge, which is constructed on the foundation of great consensus of the scientific society. This leads to the necessity of conceptual change learning and as a result, numerous studies have been done about the nature of conceptual change learning and the methodology that must be of conceptual change learning. The Conceptual Change Model of Posner, Strike, Hewson and Gertzog (1982) is the representative of these, and many researches on this thesis have tried to explain conceptual change learning from various points of view from the earlier cold (rational) model (Posner et al., 1982) to the more recent hot (affective) model (Hewson, Beeth, & Thorley, 1998; Strike & Posner, 1992, 1985). This theory explains learners' conceptual change as the change of the condition of students' conceptions; the factor of the development of students' metacognitive recognition in the conceptual ecology in which students' conceptions exist and develop. However, those studies were almost descriptions of the result of conceptual change learning by judgments of the status of conceptions before and after learning. This status of conception is related to, on one hand, what the representative mode of the status of conceptions to students or teachers is,

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while on the other hand, what the mode of interactions between the conditions of conceptual change and the components of conceptual ecology among the interactions of teacher-students and students-students in instructional classroom (Thorley & Wood, 1997; Beeth & Hennessey, 1996; Thorley & Stofflett, 1996; Beeth, 1993; Thorley, 1990) is. Also in describing the substantial process of conceptual change learning, most studies stated interpretative viewpoint of the result of change of the status of conceptions related to the mode of conceptual change (Demastes, Good, & Peebles, 1995; Hulland & Munby, 1994).

In looking at studies about students' conceptions of kinetic theory of gases in chemistry content, except for the study of Corney-Moss (1993) on the level of understanding of the theory of freshmen, studies about the theoretical viewpoint or mental model on this theory of students' constructing are rare. However, many researches generally report on 5 to 12 year-olds' conceptual construction about the basic properties of gases related to air and air pressure (Tytler, 1998, 1993; Stavy, 1986; Sere, 1986).

Most chemical theories in the chemistry textbooks are not argumentation of the complex phenomenon of nature, but a suggestion of theoretical model about explainable facets of the phenomenon. From this point of view, kinetic theory of gases is one of the theories that scientists explain and interpret nature, the object. Students often feel difficulty in learning kinetic theory of gases because of invisibility and its statistical thermodynamic property in accordance with our educational experiences. Although there has been a tendency that the studies about students' conceptions focused mainly on the kinds and patterns of the conceptions, but the studies about the representative format of the students' conceptions and about the way of constructing conceptual framework in relation to other conceptions were rare.

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The Purpose of this study

The purpose of this study is to investigate and to describe characteristics of conceptual change processes the students' experience in learning kinetic theory of gases within the theoretical framework of CCM.

- What is the conceptual type high school student construct on kinetic theory of gases?
- What are the characteristics of conceptual change learning processes high school students experience on the theory?

Definitions

Conception

Conceptions are mental representations that allow individuals to understand, explain, predict, and/or interpret an event or system. Researchers view conceptions as objects and tools of thought, while arguing that conceptions function as perceptual categories (Strike & Posner, 1992; Driver, 1989; Hashweh, 1986; Driver & Erickson, 1983).

Conceptions are the structure of units of information and the ways in which they are linked together and used (Hewson & Hewson, 1983).

In this article, we define conception following Pine's definition of concept as not to be independent entities but complex collections of relations embedded in a larger framework. He also said that these bundles of meaningful relations we call concept were, on the one hand, capable of change, and, on the other hand, could never be acquired in any finalistic fashion. Any new relations affect, to an extent, the total framework of relations.

Conceptual type

We investigated conceptual networks of 12 participants before and after the instructional unit. Three typical types distinguished those conceptual networks in three points. First, the number of

terms used in explaining scientific phenomena and the degree of sensibility of the terms. Second, the level of elaboration and organization of conceptual network. Third, the preciseness of multidimensional relationships between the conceptions concerned with other disciplinary and/or everyday knowledge.

On the basis of analysis of these data, we have reached a conclusion that three typical conceptual types exist. Each conceptual type had a very different explanatory framework as well as conceptual framework. As the conceptual framework was established in a more scientific fashion, the explanatory framework was more constructive.

Our definition of conceptual type in this article, therefore, is the format of constructing conceptual network, which acts as a deciding factor in the explanatory framework.

II. Methodology

We made use of an interpretative research design based on principles of naturalistic inquiry (Lincoln & Guba, 1985). A key feature of our analytical procedures was constant comparative analysis(Strauss, 1987) which we applied to the texts generated from the various data sources. Our intention was to develop exemplary cases for students' conceptual change learning processes with a specific emphasis on kinetic theory of gases.

Curricular, instructional and school contexts

The sites chosen for data collection were four classes in a metropolitan public high school in Korea. During the second semester of 1998, the content of chemistry was: chemical bonding; electronegativity; molecular geometry and intermolecular forces; the gas laws; kinetic theory of gases. During the first semester of 1998, students learned atomic theory, atomic and molecular weights, the structure of the atom, mole concept, chemical equations, periodic properties and the transition metals. The study was conducted as a case study, which focused on the concept of gas laws, kinetic theory of

gases and gaseous mixture.

The students who formed the core of this study were three eleventh grade males. They had been selected by the reference of typical case selection among pre-selected 12 participants. Students discussed topics of lessons and made out their worksheets in a small group cooperative learning environment. The teacher, Mr. M was experienced in teaching high school chemistry for several years. He mostly taught the content of chemistry based on the text. So researchers met Mr. M several times to introduce and discuss the methods of this study and CCM. He made an effort to lead the class in a constructivist-based environment.

Data collections and analysis

This study was implemented in the second semester of 1998 as a naturalistic study; semi-structured and in-depth interviews along with participant observations. We have selected twelve interviewees who differ in achievement score, high, intermediate, and low levels, since we wanted to know about the relationship between academic achievement score levels and conceptual change learning in Korea. Each participant was interviewed individually or in a group four times; in early and pre-instruction, mid, late and after of the semester. Each interview was taken about an hour.

In the first interview, we used seven descriptive concept-test items about kinetic theory of gases, developed on our own to examine the participants' conceptions of kinetic theory of gases. Students were asked to answer questions and then tell the interviewer the reasons.

In the second and third interviews, students were asked why they answered the way they did in their worksheets, in order to explore the change of their thinking about kinetic theory of gases. We used the instrument developed by Roth & Roychoudhury (1993) for the participants' conceptions of nature of science, scientific knowledge and chemical knowledge.

In the fourth interview, we used two descriptive concept-test items for which the participants had

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two response choices: true or false about kinetic theory of gases and gaseous mixture that we developed, which needed to be justified afterwards.

In addition, the interviewer asked the participant how they study science, chemistry in particular, what they think is the most fundamental knowledge of chemistry, what is the most difficult job in learning chemistry, and what kind of environment they want to be learning science.

III. Results and Discussion

This research focused on the ways and levels in which students construct fundamental chemistry conceptions on kinetic theory of gases through analyzing students' conceptual types and conceptual change learning processes. For this we examined the characteristics of students' conceptual networks and of their change.

This study was implemented by a case study. In monitoring the progress of the conceptual change unit on kinetic theory of gases, we collected data from detailed interviews with 12 students, videotape footage of classroom practices and the assembled written work of all students. In the progress, we found it valuable to focus on three students in detail and construct case studies of their experiences and learning. They provide rich descriptions of the phenomena of teaching and learning. For us, the case studies became the focus for our own evolving understandings of conceptual change learning. Although they addressed the learning of only three students, the detailed analysis and interpretation led us to an enhanced understanding of many aspects of conceptual change learning processes.

Also three types of learners were examined in the ways they incorporate new knowledge into pre-existent conceptual structures or conceptual networks. We could then distinguish three conceptual types by the level of organization and elaboration of conceptual networks students constructed on kinetic theory of gases. They were superficial terms-speaking, partial sense-making, and causal sense-making conceptual types. These three types constitute a spectrum in line but not discrete, and

thus sometimes fall into more than one type.

We drew conceptual networks of typical conceptual types according to the previous definition of conception (Fig. 1, Fig. 2, Fig. 3).

Characteristics of conceptual change learning processes by conceptual types[1]

We investigated the conceptual change learning processes each conceptual type learner experienced, describing them at each of the four periods throughout the instructional units: before learning, first half of the unit, second half of the unit, and after learning.

Consequently we found that the most important component of conceptual change learning is students' psychological viewpoint of learning such as motivational beliefs, which decide the purpose and strategy of individual learning, and these were strongly affected by both the conceptual framework by conceptual types and epistemological commitments. Here, the conceptual framework refers to the degree of explanatory consistency and the level of organization and elaboration of conceptual network.

1. Superficial terms-speaking type (Gu)

Students in this category can use scientific terms but this is proved to be superficial identification based upon individual experiential knowledge. They usually can not make sense of the terms based on their scientific understanding. Therefore, the conceptions are not fixed on any conceptual structure, thus failing to form a meaningful conceptual network. Gu is a participant who was typically this type.

Gu had insufficient explanatory consistency about scientific concepts. Motivational beliefs like

[1] Conceptual types of students

Superficial terms-speaking	Partial sense-making	Causal sense-making
Gu	Nam	Do
Lee	Min	Byun
Sung	Ahn	Jin
Chang		Tae
Kim		

individual learning purposes and self-efficiency, rather than epistemological beliefs, acted strongly as a driving force for science learning.

A. Before instruction

He could not understand basic scientific knowledge as pieces of conceptual knowledge having scientific meaning. His conceptions were restricted to experiential knowledge. Alternative conceptions he already had constructed lacked internal consistency, and therefore he often gave different explanation according to context.

For example, when he was asked "what will happen to the air in the sealed flask?", he answered "the massive component will sink and the lighter air will rise up." He explained that the larger the size of molecules, the more massive they will be. He could not discuss in such terms as atomic structure, molecule, and molecular weight etc. at the level of conceptual understanding, as he was discussing in terms of everyday knowledge.

He said "gases move freely in the balloon..." to the question of " what are the volumes of oxygen and nitrogen in the flask and balloon?" He could not, however, say the exact volume of component gases but give an answer to the ratio of composition when he was asked to find specific values.

He thought that in the flask, the air existed such that each gas occupied different spaces, while in the balloon, component gases mixed together because the flask is fixed and the balloon is translatable freely. This acted as a barrier to the connection and incorporation of experiential knowledge and scientific knowledge by the participant, thus causing distinction between school knowledge, which he believed to be rational and everyday knowledge.

B. First half of the unit

He confused microscopic world with macroscopic experiential world, and hence failed to make scientific sense-making. He could not successfully construct theoretical framework of scientific

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knowledge and meaningful conceptual network.

For example, he said, "gases occupy different space according to their molecular weights." When they entirely diffused. This means that he failed to construct proper understanding of gaseous mixtures. This seemed to have originated by defective conceptions of particulate properties of matter, and also by confusing microscopic phenomena with macroscopic experiences. In other words, He thought that those phenomena were caused by the division of individual components of gaseous mixture (e.g. nitrogen and oxygen for air), and thought each component of gaseous mixture occupied separate spaces independently.

In another instance, on the diffusion of nitrogen and bromine, he said, "the two gases tend to come driven toward the more massive bromine. This is the same case with the diffusion experiment of $HCl_{(g)}$ and $NH_4OH_{(g)}$". This allows us to know that he did not have a sufficient understanding of uniformity of gaseous mixture and dynamic equilibrium yet.

Fig. 1. About Here

C. Second half of the unit

His learning method heavily depended on rote-memorizing strategy, especially substituting things to equations in any situations. But as he had poor understanding of basic physical constants and equations, he often failed physical unit operations and therefore in many cases he could not solve the problem.

He often relates learning topics and theses to formal equations merely, thus when the situational context of the problem is coincident with the conditions that the equations must be applied, he usually proved successful. But, in the cases of the necessity of unit transformation or proper consideration of misleading conditions, he often failed.

He had not the proper understanding of the role of theories and theoretical models in science

learning, but also could not construct theories by himself and theoretical models about scientific knowledge and had insufficient reflective thing skills and metacognitive knowledge.

He told that "there is no need to think about it" to the question of why the presupposition of ideal gas is needed. He explained the reason that we must believe the content of the texts because it states only the absolute truth. He had an idea that the model of ideal gas, laws of ideal gas and the theory related to it are not the object of his own thinking, but of the scientists or textbook authors.

When he was told that air, along with any gaseous mixture is like continuously moving groups of people in the same classroom, he could not understand the uniformity of gaseous mixtures, did not know the volume of each component gases and partial pressure.

D. After instruction

He achieved somewhat enhanced structural development of conceptual network throughout the instructional unit, but the degree of organization and elaboration was still insufficient.

For example, you can see in Fig. 1 and Fig. 2 that he maintained misconception on the uniformity of gaseous mixture before and after the instruction. As to the molecular motion of gases, he related to only molecular weight, but after the instruction, he could explain the motion as being associated with kinetic energy as well as molecular weight. He committed error of causal relations in the explanation of molecular weight when he described average speed, average kinetic energy, and partial pressure of gases as the result of collision number of gases. In addition, he misunderstood the correlation of partial pressure and molar ratios. Finally, the hierarchic structural relations of concepts in conceptual network were not clear, additionally failing to form scientific sense-making of the concepts of scientific terms.

Fig. 2. About Here

2. Partial sense-making type (Nam)

Some students partially have scientific conceptions, but conceptual network is formed locally and is not substantial because of their failure in constructing meaningful context as a whole. Explanatory frameworks of viewing phenomenon are not consistent. It usually seems that empirical and scientific explanations about phenomenological understandings coexist, while scientific knowledge is acknowledged as objective. Nam is a typical case of this type.

Nam had a partially systematic explanatory structure of scientific sense-making and thus could not totally understand scientific concepts. This led to repeated production of alternative hypothesis in learning new scientific knowledge. He had a tendency to internalize external authorities like textbooks and/or statements of teachers when he lacked active sense-making, hence partially constructed concepts about scientific knowledge had different explanatory structures from contexts to contexts.

A. Before instruction

He had a clear definition of his own about scientific terms and proper concepts of scientific knowledge, but these were somewhat unstable, developing alternative framework of such conceptions in addition..

For example, to the question of diffusion of nitrogen and bromine, he said "nitrogen has much less speed because of its smaller molecular weight that diffuse more slowly." Although he knew that the less massive molecules had more speed, his application of the value of speed to diffusion speed was not right. In other words, academic knowledge was not strictly established as scientific knowledge and, therefore, concepts were incompletely constructed. The fact that he could not consider the constancy of average kinetic energy led to indistinctness of hierarchical organization of concepts. Also, he said "because there is an ending point in the diffusion of gases, diffusion can't occur any more and the molecular motion of gases stop at that instance. This is the same with chemical reaction

where the reaction stops after the product had been produced." He misunderstood microscopic phenomenon and dynamic equilibrium, also confusing particulate property of matters with linear macroscopic phenomenon. He failed to incorporate experiential knowledge to scientific knowledge, developing and rationalizing alternative frameworks instead.

He thought that pressure decrease in ice water was caused only by the drop in temperature. He could not explain it in relation to average kinetic energy of gas molecules or the inner pressure decrease of balloon. This is the result of mere application of Boyle –Charles's Law. This indicates that he is apt to apply chemical equations once having successfully learned, and this occurs in spite of situations or contexts. This is considered to be a method of learning and understanding that he developed in order to carry out problem solving. He explained that the inner pressure decrease of balloon in ice water was the same phenomenon as the air pressure decrease experienced when climbing mountains.

His concern is focused on grades whether he can understand the concepts or not. Accordingly, his learning strategy is mainly dependent on rote memorizing contents of text, statements of teacher, workbooks etc. He is highly dependent upon extrinsic authorities and thus a very passive learner.

He has a good deal of fundamental scientific concepts, but cannot organize or systematize them in the conceptual framework as sensible contexts.

For example, he can explain about the molecular size and molecular weight on the basis of atomic size and atomic weight. But to the question of "why are nitrogen and oxygen molecule represented as N_2 and O_2?", "why aren't they represented as N_3 or O_4?", he answered "I just use them because I learned them in middle school." He postponed meaningful sense construction and conceptual understanding, saying, "we learn in school so the knowledge from school is the absolute truth." He lays stress on rote memorizing, and was satisfied with the level of understanding and problem solving

which will guarantee a good academic score.

Fig. 3. About Here

B. First half of the unit

His learning strategy is mainly rote memorization for problem solving (mere substitution values to equation). He cannot constitute sensible context as a whole, and lacks explanatory consistency.

He does not know the fact that gaseous mixture exists in the gas gathering tube because water vapor is evaporated over the water surface when oxygen is gathered via gas capturing over water. Although he answered that it is the same as the ratio of partial pressure when asked, "what is the volume of each component gas?" He also misunderstood that a molecule composed of three atoms: water vapor, for example, is heavier than a molecule composed of two atoms such as oxygen. He said that because water vapor has larger molecular weight than oxygen and they existed in a closed system, water vapor changes to water so that it comes down to mix with water. Moreover he induced an analogy that this phenomenon was the same as the phenomenon of sealing the mouth of pot with our fingers to have the fume change to water. He confused water vapor with fume, which disabled him to explain condensation of water vapor and phase change of water. In summary, he uses learning strategy to understand and memorize school knowledge fragmentarily to insert everyday experience or preconceptions into temporary alternative frameworks.

Apparently he is proficient with a concept and applies it successfully, but due to the lack of understanding fundamental principles of theories, he fails to apply it to new phenomena.

We gave him a series of experimental data of real gases, hydrogen and carbon dioxide about temperature, pressure and volume. Then he was asked to draw the relationships between the variables and to predict which gas was more approximate to the ideal gas and was asked to give an explanation of the reason. He adequately drew the graphs, properly interpreted them, and predicted the more ideal

gas correctly. But, regarding the reason why hydrogen gas is more ideal than carbon dioxide, after keeping silent for more than five minutes, he answered "Nobody asks such questions", "I was taught those has kept their original figures such a form", " Isn't it something that I have no need to know?"

At last, he gave an alternative explanation that as the size of the particle become smaller, the number of collisions decreased to better fit gas laws. This explanation contradicts his statements that the smaller and the lighter gas molecule, the faster the speed in gaseous diffusion. It is proved that he has only superficial knowledge about ideal gas conditions, not proper understanding of the meaning and necessity of the conditions. In other words, he cannot make sense of the ideal gas equation of state and of theoretical concept of ideal gas law.

C. Second half of the unit

Because of the lack of incorporated complete understanding about the core concept of theory, he generates continuously ad hoc hypothesis and alternative frameworks. He can accomplish developed conceptual networks, but it is not wholly scientific.

He explained that pure substance approximates ideal gas more than compound does. For example, he suggests hydrogen molecule as a pure substance in his saying the condition of ideal gas. He cannot distinguish the difference between a pure substance and a simple substance, nor a pure compound and a simple compound. He explained the reason as being that carbon hydroxide is composed of different kinds of atoms while hydrogen is composed of the same kinds of atoms. He uses his naive conceptions in explaining the property of ideal gas, and continuously generated alternative conceptions by superficial observations and/or preconceptions. Also, to the question of the volume of gases when the temperature and pressure of the gas are changed simultaneously, his answer is that "I can't think of it because I can't apply Boyle's Law or Charles's Law to the question." He emphasizes only the equations and where to apply them instead of trying to know why the equation is needed,

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what it means, and how it is used. He was not extending his knowledge to scientific theories, thus being deficient of integrated understanding of ideal gas law.

D. After instruction

He uses multiple perspective representation of reality in the process of generating a better explanation about a task; he can extend his concept and establish hierarchical organization of concepts.

Before learning about the kinetic theory of gases, he thought that the average speed of gas molecule related to its molecular weight, and molecular weight increased with the increase of the number of component atoms. After the instructional unit, he thought that the mixture of gases had a constant average kinetic energy within the condition of constant temperature, and was able to explain the precise causal relationship of average speed and molecular weight. But he confused irregular motion of gases with heterogeneity. As a result, before the instruction he explained the volume of gaseous mixture as "inversely proportional to partial pressure", but afterwards, he answered, " volume of gases increases as the molecular motion becomes vigorous, and this is caused by the more collision number of the bigger molecules. From this, we can see his particulate perspective is not completely perfect yet, which can be interpreted as the organization of conceptual network that is not yet properly elaborated (Fig. 4).

He rejects the need of reflective thinking, lacks effort of active thinking, and only concentrates on obtaining solution of a given problem. He does not concern scientific conceptual construction, extension, and elaboration, but interested in acquiring a good grade through simple problem solving by accumulation of fragmentary knowledge.

To the true-false type questions, if he has answered and knew whether it was correct or not, he never tried to prove or falsify it. Even if teacher gave him a question that required a specific answer,

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he never endeavored but gave answers like "I have already solved the problem."

When he was asked to answer the question "what is the method that makes it possible to know which gas is faster in gaseous mixture of nitrogen and oxygen?" he said, "I don't know" and made no effort to obtain the value.

Fig. 4. About Here

3. Causal sense-making type student (Do)

Besides the previous two types of students, the other students comparatively construct scientific conceptions. For these students, the hierarchical structure of conceptions is well formed. Other discipline-related knowledge is rich and explanatory consistency is one of the characteristic properties. Therefore stable conceptual network is formed. Do is a typical case of this type.

He has appropriate proper scientific concepts and is able to construct hierarchical structure of concepts by himself; his conceptual network includes lots of disciplinary conceptual knowledge. He can be distinguished from other conceptual type students in that he maintains explanatory consistency. His conceptual framework is very stable. Sometimes, however, although he understands concepts in the classroom environment, he does not have the ability to transfer his newly acquired knowledge to other contexts.

A. Before instruction

He uses concrete and definite terms to explain phenomena, and also understands their scientific meanings well. He makes sensible conceptual network of scientific concepts.

He gave an almost perfect explanation about the state of equilibrium regarding inner and outer pressures of gases when the outer pressure increase causes the inner pressure increase. Interactions in a closed system and the concept about equilibrium were finely constructed in his mind.

He gave explanations on concepts like closed system, average kinetic energy of gases, gaseous

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pressure, gaseous volume, and their causal relationships. He organized a conceptual framework of scientific knowledge not only in the connection with internal energy of matters and basic concepts of gaseous kinetics but also applying other disciplinary knowledge such as physics, biology, etc. He maintains explanatory consistency and builds a scientific conceptual network (Fig. 5).

Fig. 5. About Here

B. First half of the unit

He sometimes challenge problem solving in new situations by means of applying already mastered principles, but he sometimes makes mistakes in selecting which principle to apply since he has not prioritized those principles.

In the case of oxygen collection by displacement of water, he thought that the volume of component gas was proportional to the number of gas molecules in a collection flask. At this occasion, he said, "in chemical reaction equation, $2H_2O_2 \rightarrow 2H_2O + O_2$, volume of steam is double the volume of oxygen gas because Avogadro's law tells us that the ratio of volume, coefficient, and number of molecules is the same. His intension to solve problems by linking his knowledge of chemical stoichiometry to his knowledge of Avogadro's law was inadequate because the steam in the mixture is not caused by the chemical reaction but by the evaporation of water inside the collection flask. Misunderstanding the experimental equipment led to failure in grasping the problem situation, causing failure in problem solving. It proves that procedural knowledge and/or process skill knowledge are important in adequate construction of conceptual knowledge since that contextual or situational understanding decides exactness.

C. Second half of the unit

He can act as a leader among his peers and knows the content knowledge and scientific reasoning skills that his peers need, thus being able to provide proper hints. He focuses on given

situations precisely and makes decisions through logical reasoning.

For example, regarding the air inside a cylinder sealed by a piston, although his peers could not answer when the teacher asked what is the effect of temperature change on air, he tells his peers each applicable gas laws, and gives an advice while explaining specific content.

His conceptual commitments already acquired are not changed so easily, since he has strong beliefs about explanatory consistent principles of his own system of knowledge and perception. If he finds inconsistency in his logical reasoning and in explaining phenomena, he continues to make explorative thinking since he realizes internal contradiction in spite of his desire to protect his own explanation or theory.

When the intervention about the volume of component gas in gaseous mixture was demonstrated in class, initially he could not give a precise answer. For example, to the question of the total pressure of component gases when the cork was opened in the vessels that were connected to 3 L of 2 atm hydrogen to 2 L of 5 atm oxygen, he said it was 16 atm, which was the same as the ratio of molar number. Since this answer ignores the volume of vessels, it is wrong. Therefore we gave him another question. "when the mixture of steam 1 mol and hydrogen 2 mol is contained in a vessel, what is the volume of each component in order to find out each partial pressure? " He answered that the volume to obtain partial pressure of steam was 1 L, while that of hydrogen was 2 L. In other words, he kept thinking that the ratio of volume and molar number was proportional to each other which he explained this way: "When the molar number is constant, the temperature and the volume is constant. Since this ratio is 1:2, all ratios are 1:2."

D. After instruction

He is proficient in fundamental scientific knowledge and has the ability to apply other disciplinary knowledge when learning science. His proper scientific basic conceptions of chemistry

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make it easy for him to incorporate new concepts to scientific concepts, making it more effective to experience conceptual change learning through Socratic instructional intervention than other conceptual types.

Regarding molecular motion of gases, his fundamental conceptual understanding is well organized and is mixed with other disciplinary knowledge, while he has precise concept of basic gas laws. He comparatively develops and easily extends scientific concepts of gases in the classroom exercises and interviews (Fig. 6).

Intervention by teachers using analogies can provide decisive assistance to cooperate new knowledge to prior conceptions and conceptual network, and consequently to construct scientific concepts.

Despite his initial explanation about the volume of component gases, which was improper, the analogy of two groups of persons made it possible for him to understand the fact that the volume of component gases was the same with the vessel volume in a closed system, having the same value.

Fig. 6. About Here

IV. Conclusions

If we can find a way of providing taxonomy of conceptual relations we will be able to predict and find ramifications for research in cognition, developmental psychology, and epistemology. Understanding causality of motivational relations also leads to ramifications for research in affection, motivational psychology, and socio-cultural beliefs. All of these, along with other relevant areas too numerous to list, will influence curriculum development, instructional planning, teaching, and learning, which are the cornerstones of education.

We have some conclusions on the basis of this study.

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First, students' preconceptions included a lot of alternative conceptions. This was mainly because they confused experiential knowledge with scientific knowledge. It was also because scientific sense-making was incomplete throughout contexts where they constructed concepts partially.

This related to the inconsistency of physical mental models in the process where students' experiential knowledge about the real world incorporated to scientific knowledge. Superficial terms-speaking and partial sense-making type students differentiated the explanatory mental model of the real world and scientific world. On the other hand, as in the case of causal sense-making type students, as the learner accumulated more fundamental scientific concepts and more accurate understanding of theoretical concepts, he incorporated these concepts much better, which led to substantial conceptual change. From this, we can conclude that it is very important for teachers and students to construct theoretical mental models and that is needed in teaching and learning generative self-regulatory strategy so as to promote reflective thinking and transfer of knowledge.

Second, the causal sense-making type students experienced effective successful conceptual change rather than the partial sense-making or the superficial terms-speaking types. This implies that teachers and science education researchers need to understand students' conceptual types, and to develop instructional strategies and teaching series accordingly. This can improve active sense-making of the students and provide an opportunity of experiencing conceptual change learning.

Third, students have the general tendency to believe in objectivist viewpoint, rationality, and absolute truth of scientific knowledge. This is the key driving force that make students very passive as learners. For example, superficial terms-speaking and partial sense-making type students thought that science was a system of knowledge of extrinsic authority, and the progress of scientific theory substantially belongs to scientists' peculiar working domain. When a student is an active sense-maker and learner, he is able to understand fundamental conceptual knowledge properly, thus allowing

himself to experience conceptual change successfully. Accordingly, learning about epistemological facet of the nature of scientific knowledge is essential for students and they must recognize their role as learners. In other words, the learning process must reflect that scientific knowledge is a theoretical concept from the Great Discourse of scientific society by scientists' negotiation.

Fourth, students distinguished between what is the necessary knowledge and what is not on the basis of individual motivational dispositions like extrinsic/intrinsic authority of scientific knowledge, individual learning goals, and self-efficacy. In most cases, the failure in constructing sensible theories and theoretical models about scientific concepts follows this. This implies that there is a necessity to stress learners' voluntary psychological elements for self-directed learning, which must be a driving force of the learners' own.

V. Implications

New reformatory movement for science education is based on new epistemological beliefs about the nature of scientific knowledge. Hence, in science education, new recognition of scientific knowledge, not as an inheritance but as sense-making is strongly needed. This provides new ways of thinking and methods about the nature of learning, the role of learners, curricular organization, and the construction of teaching sequences.

This study is significant because it interprets how students understand and provides insights into the patterns of knowing and learning methods in restructuring the student understandings and interpretative frameworks. This will eventually have a significant impact on textbooks, methods of instruction, curricular courses for students and teachers.

In relation to the result of this study, we can advocate the followings.

First, the rich fundamental conceptual knowledge and the precise understanding of core theoretical concepts allow learners to experience successful conceptual change. Therefore, the importance of

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fundamental disciplinary conceptual knowledge must be considered important, which must be reflected in the process of teaching and learning. Through understanding conceptual ecology that decides the type of conceptual frameworks and influences on them, the proper teaching sequence that will promote students to learn can be established.

Second, by recognizing the importance of a learner's motivation based on the psychological and sociological viewpoints, effective instructional strategy must be developed and applied. The result of this study shows that the role of a learner as an active sense-maker is strongly restricted by his unlimited belief on extrinsic authority, and the motivational belief according to socio-culturally generated viewpoint for social existence. This asserts the necessity of applying motivational tendencies of students to specific substantial science educational settings.

Third, this research is about the learner's conceptual frameworks on kinetic theory of gases and about the characteristics of conceptual change learning processes followed by it. There is a need to study the conceptual frameworks of students around domain-specific knowledge of chemistry.

Fourth, it is necessary to further increase the number of types to categorize students to more thoroughly understand learners' conceptual frameworks to help chemistry instructors to teach better and their students to learn more effectively.

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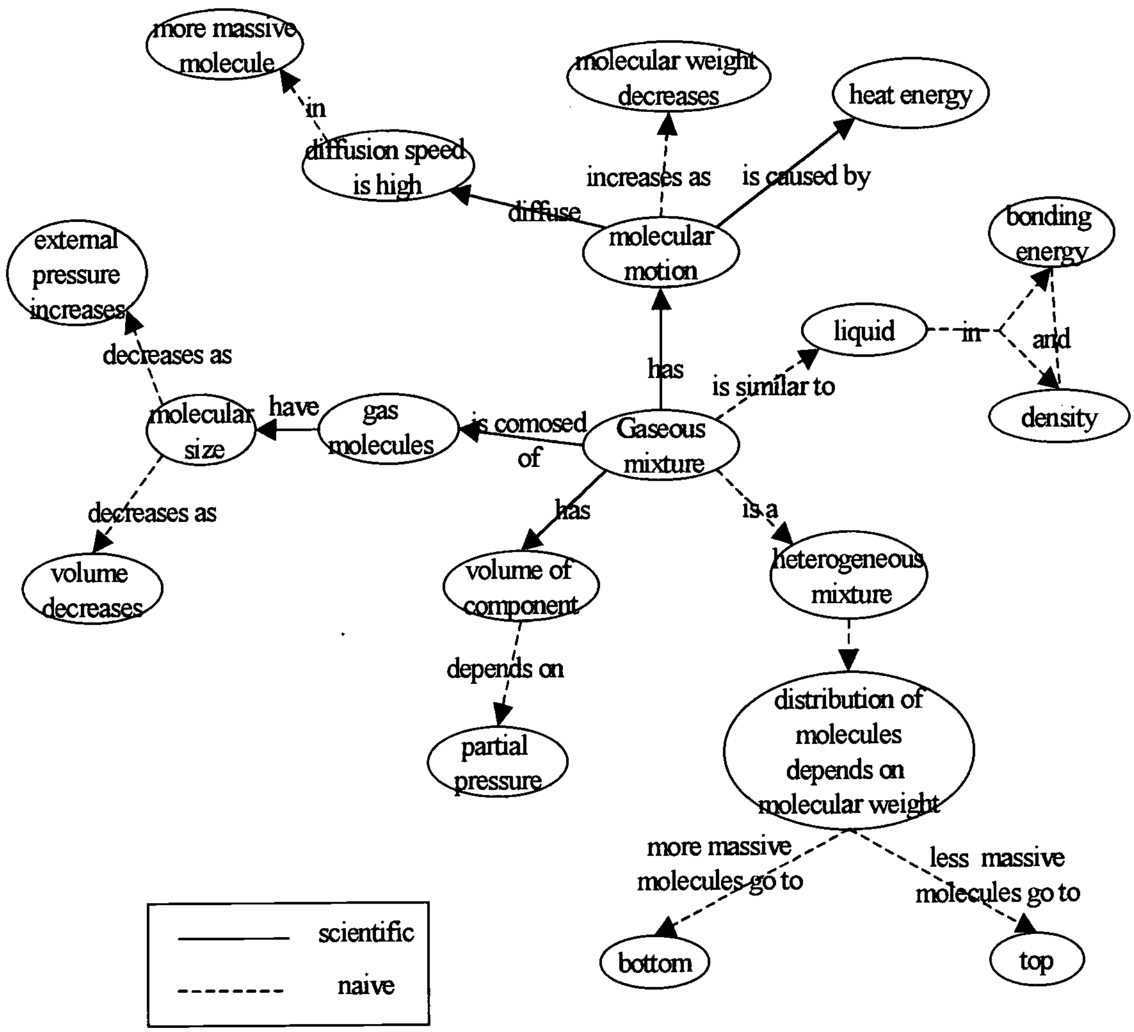

Fig. 1. Gu's conceptual network on kinetic theory of gases before instruction.

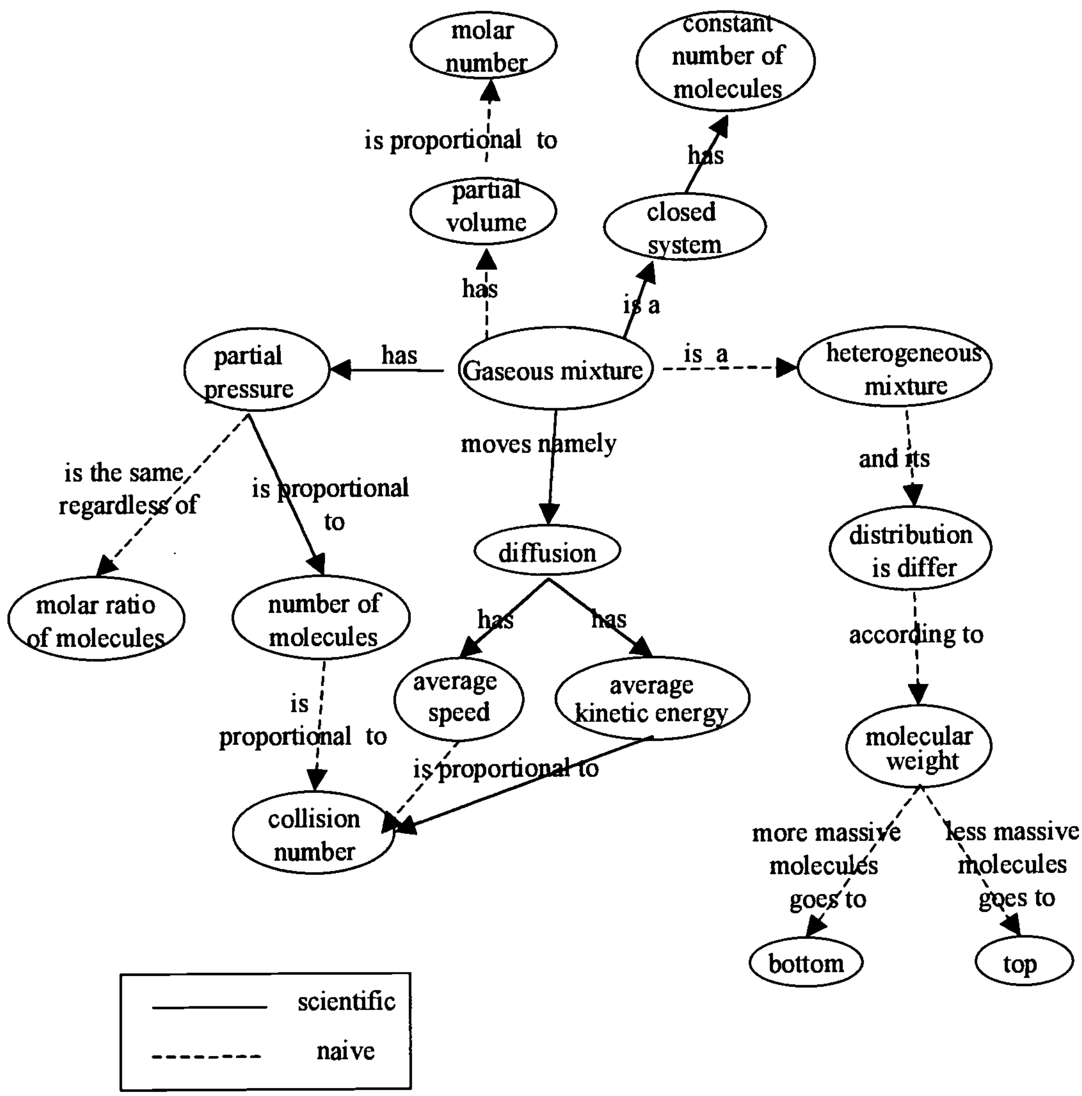

Fig. 2. Gu's conceptual network on kinetic theory of gases after instruction.

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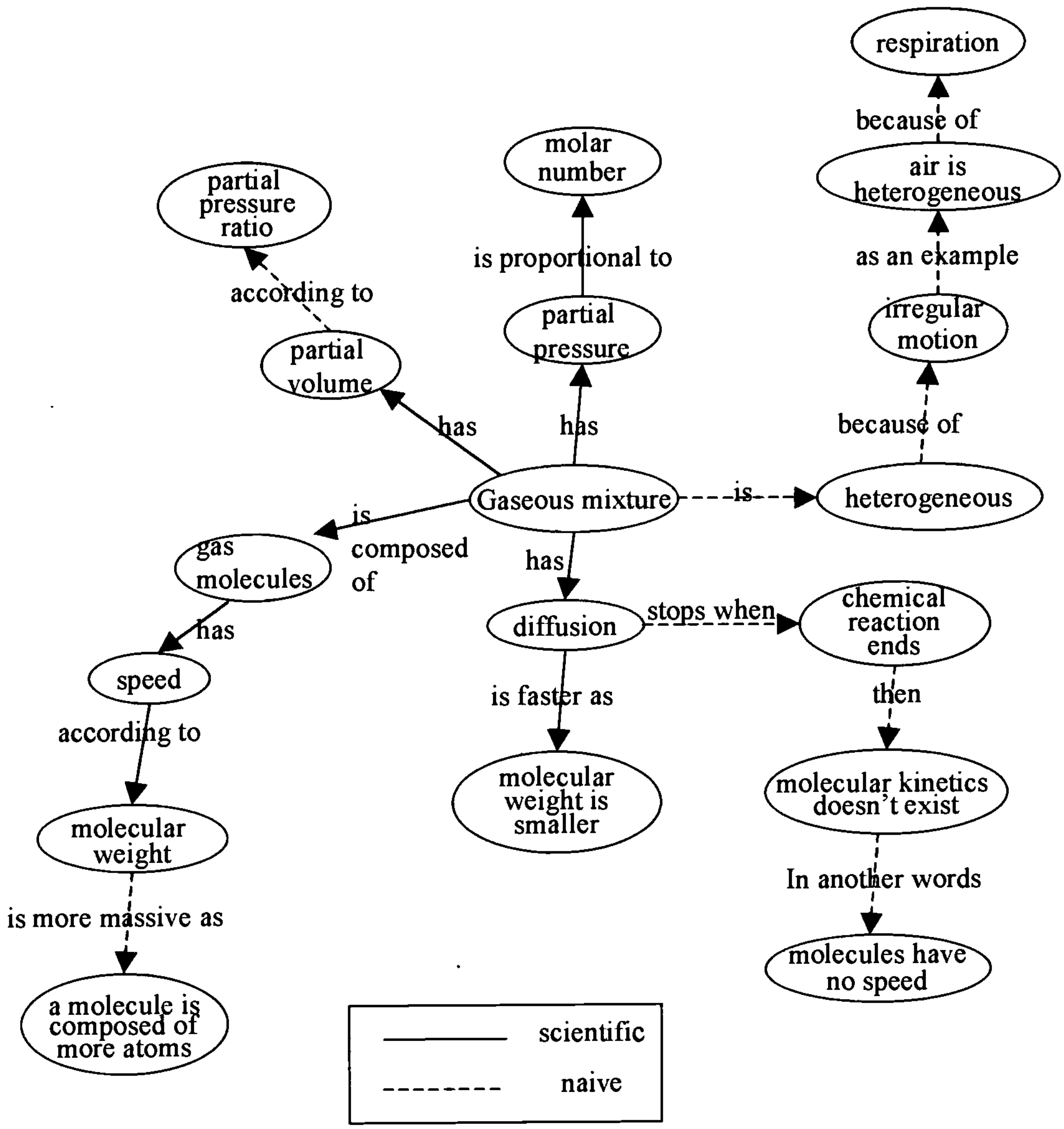

Fig. 3. Nam's conceptual network on kinetic theory of gases before instruction.

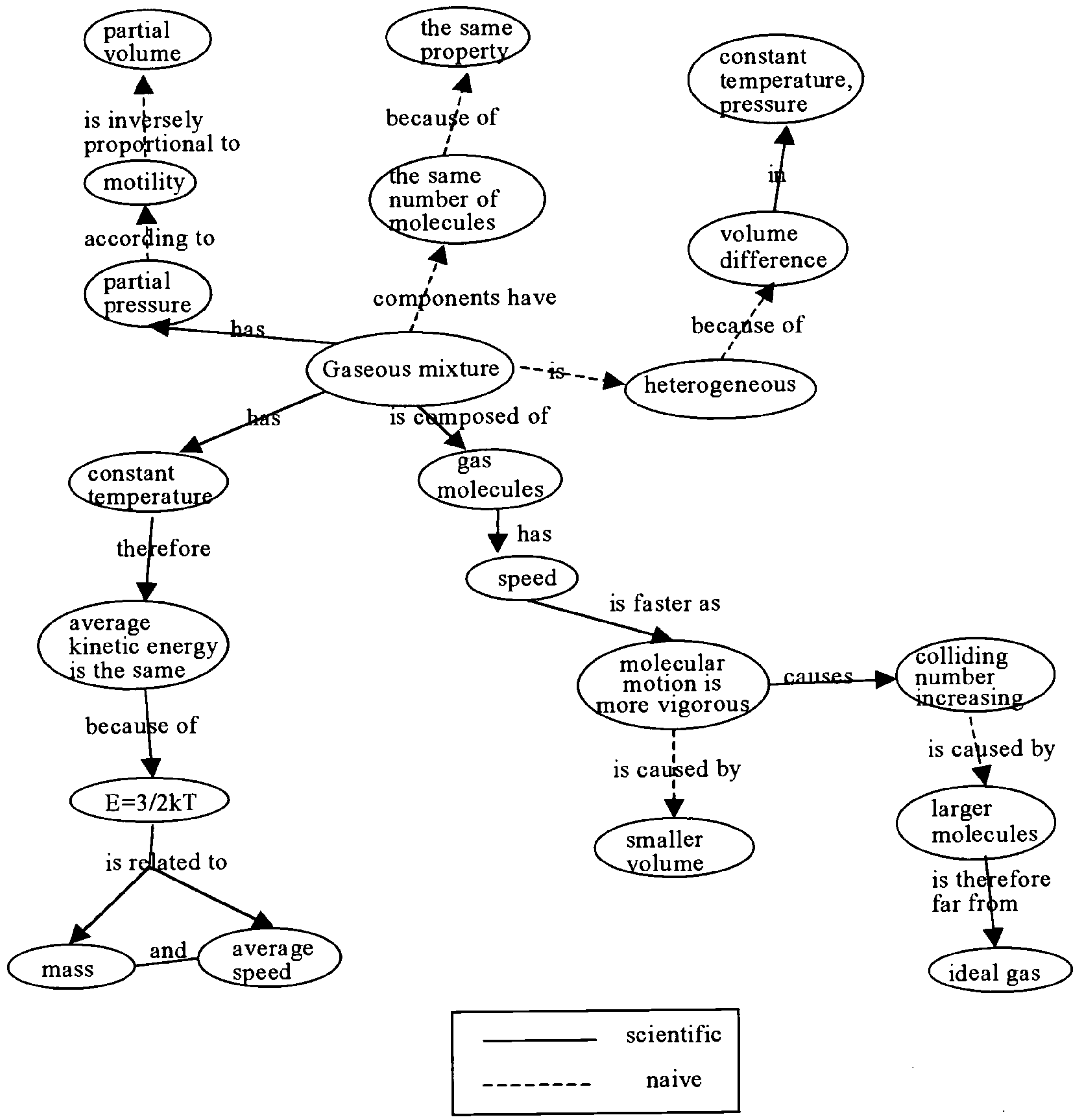

Fig. 4. Nam's conceptual network on kinetic theory of gases after instruction.

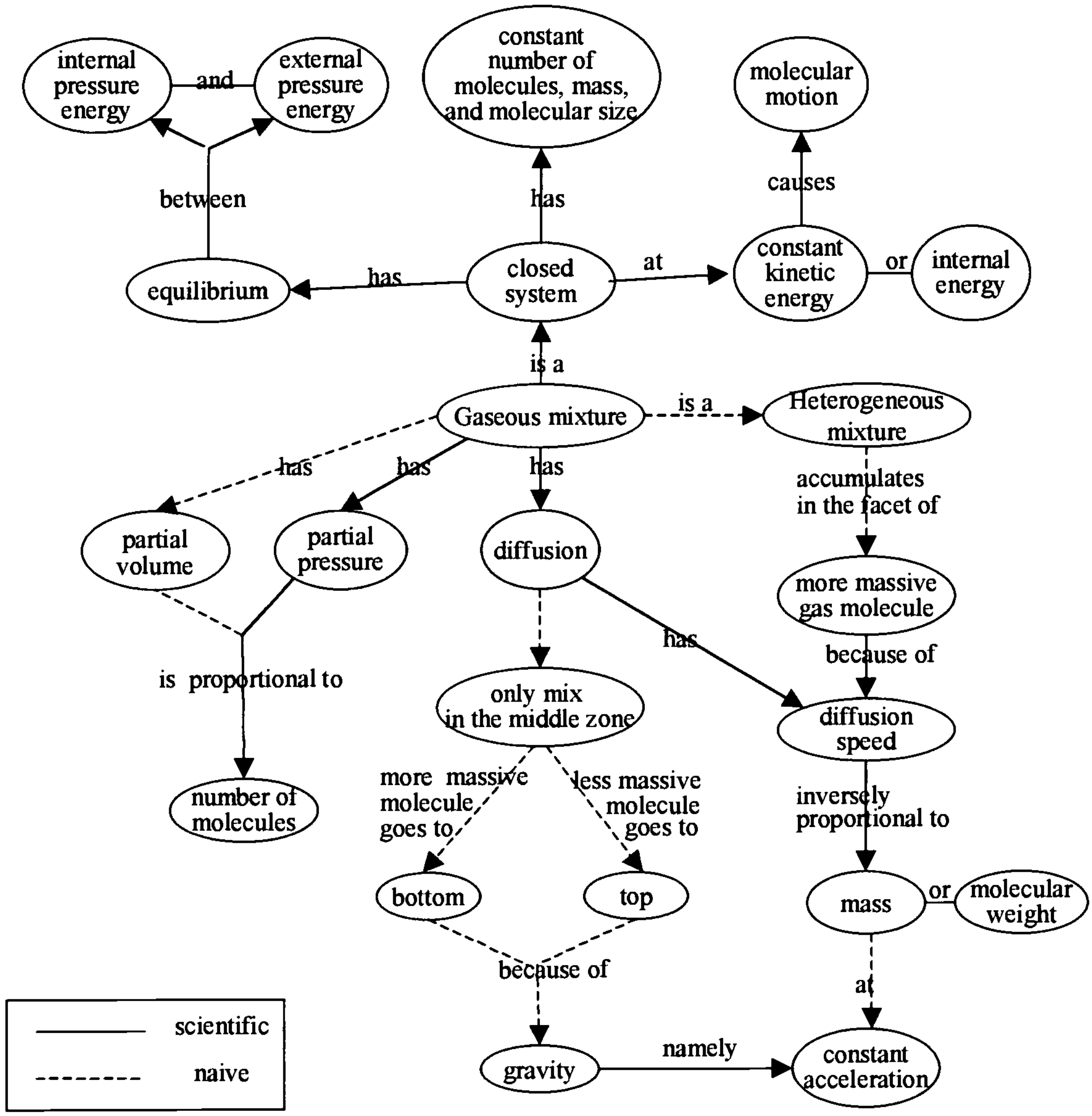

Fig. 5. Do's conceptual network on kinetic theory of gases before instruction.

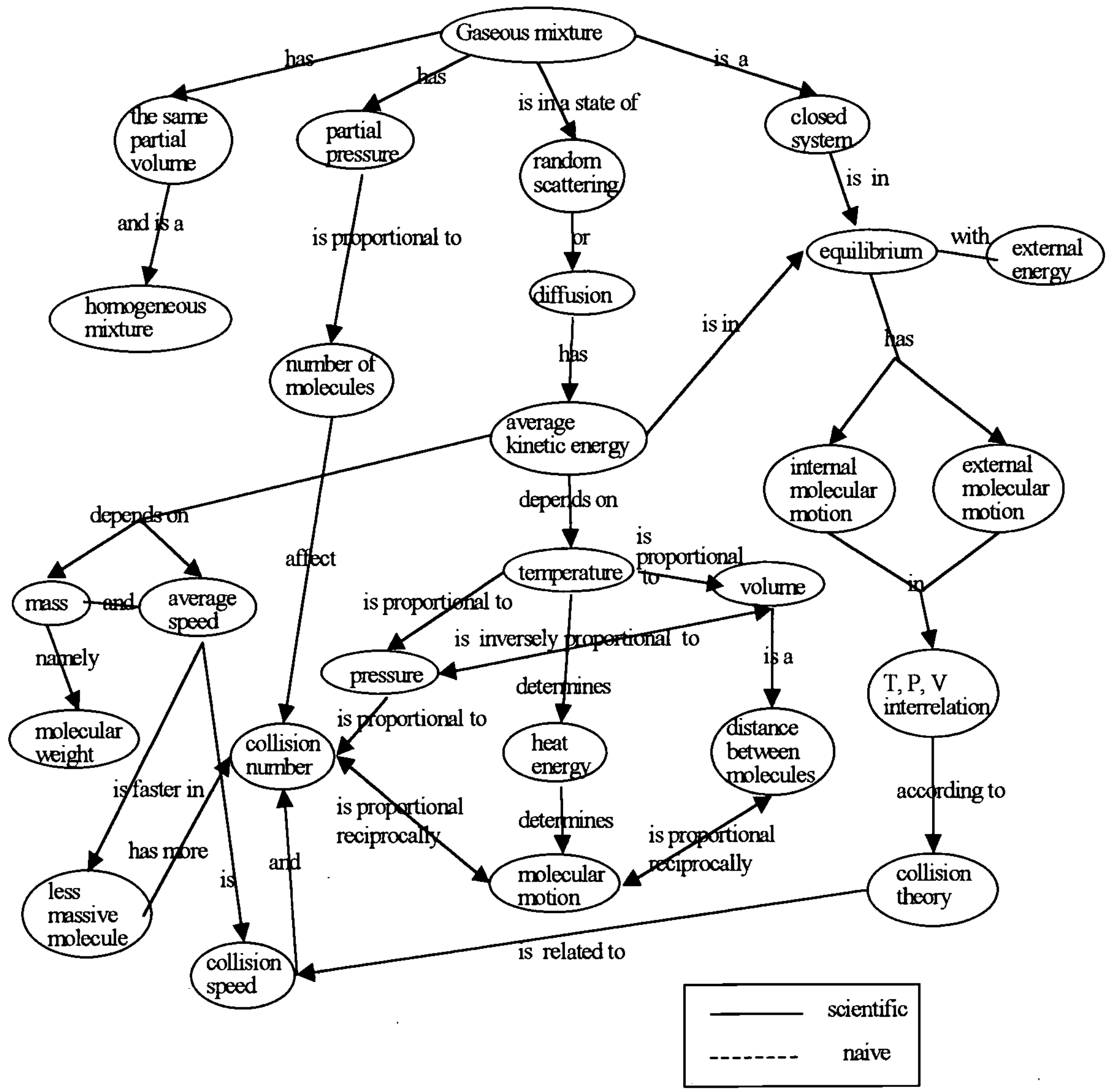

Fig. 6. Do's conceptual network on kinetic theory of gases after instruction.

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